

# speleonics 5

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1986

VOLUME II

NUMBER 1

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## SSB 2-WAY VOICE CAVE RADIO

Schematics !

## SPELEONICS 5

Volume II, No. 1, Summer, 1986

**SPELEONICS** is the quarterly newsletter of the Communication and Electronics Section of the National Speleological Society. Primary interests include cave radio, underground communications and instrumentation, and cave-related applications of amateur radio. Membership is unrestricted (NSS membership not required). Membership, which includes four issues of SPELEONICS, is \$4.00 in

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### ----- EDITORIAL -----

The editorial of Speleonics #1 listed 7 projects that the Communication and Electronics Section thought were important. We have done well on 5 projects.

-We have a quarterly publication, it is on-time and well-received by our members.

-We have our own session at the NSS Convention. Both at Frankfort, Kentucky and at Tularosa, New Mexico we had lively sessions attended by about 40 people each time.

-We have a bibliography of cave-radio articles which is growing.

-We are developing a network of contacts internationally to report on developments.

-We have updated the NSS "Caving Information Series" on Communication.

Where then do we need to look, to review last year's projects to see if they are still important to us? The two projects of the original seven are "Designing high-performance, easily reproduced cave-radios" and "Working with the National Cave Rescue Commission to...(improve the utility of communication equipment)".

I feel both of these items are still key objectives. I feel cave radios can make caving safer, and rescues more efficient but to do this, high-performance, cheap radios are needed.

This issue carries a description of the Alberta Speleological Society radio which developed from

early work by Pete Hart of the Westminster Speleological Society in England. The unit has high performance; two-way voice to over 220 metres depth on 10 watts PEP, with small portable antennas; but cheap and easily built it is not.

Surely one way to approach high-performance and easy construction is to utilize commercially available radio systems. One method for licensed amateurs would be to experiment on the 160 metre band which Nevin Davis predicted could be useful for voice<sup>1</sup>; A conclusion supported by experiments by Larry Jack<sup>2</sup>. A second approach would be to build a converter to change the commercial radio signals to lower frequencies for cave-radio use. I am currently working on such a system to use CB radios at 115.2 kHz (to be compatible with existing ASS cave-radios).

Affordable voice-communication is the next challenge for the Cave Communication and Electronics Section.

Let's rise to the bait!

--Ian Drummond

<sup>1</sup> Optimum Frequencies for Underground Radio Communication. N. Davis, Nat. Speleo. Soc. Bull. Vol 32, #1, 11-26, (1970)

<sup>2</sup> Underground Radio is a Dirty Business. L. Jack, 73 Magazine, 57-59, Sept. 1975.

Dear Ian,

Frank Reid, in his editorial in Speleonics (4) 1 (1985-86) mentions my early statistical study in which I predicted the number of entranceless caves in Pennsylvania and West Virginia, and implies that my finding that entranceless caves "are numerous but very short" is in contradiction to the fact that Indiana's two longest caves were once both entranceless.

First, I extended my study to many other areas, including Indiana, in another paper (J. Geol, 74 (5) Part 2 798-830 (1966)). Based upon the data then available, the finding for Indiana was that there were expected to be between 85 and 281 (95% Confidence Interval) entranceless caves in Indiana over 1000 feet long, with an expected mean length of 2159 feet. At the time, 41 caves over 1000 feet long with natural entrances were known.

The lengths of caves were also studied, and were found to be hyperbolically distributed. With the parameters for this found then, one can predict that there are expected to be from 0.6 to 1.5 (95% C.I.) caves over 100,000 feet long, with or without entrances. That two are known is therefore not surprising.

More complete data available today, analyzed as was done in 1966, would undoubtedly increase these estimates. However, the possible data base for a reanalysis is being degraded as more caves are discovered or extended by digging, unless such alterations are recorded and always accompany published data.

Sincerely,

**Rane L. Curl**  
Department of Chemical Engineering  
University of Michigan  
Ann Arbor, MI 48109-2383

REPLY

Dear Ian,

Academic paranoia is an occupational hazard of theoreticians. By citing spontaneous formation of entrances in recent history, I intended to support Curl's finding that the probability of having an entrance increases with a cave's length. (Paradoxically, formation of entrances tends to fragment long caves into short ones.)

Actually, the entrancelessness of the caves in question is a matter of semantics; both were subsequently found to "connect" to "smaller" known caves.

Someday I hope the good professor will allow me to photograph him operating a cave radio, to illustrate the esoteric technique of using the curl to find the divergence!

73,

**Frank Reid**

Dear Frank,

It would probably be worthwhile to print the provisions of (FCC Rules and Regulations) Part 15 that apply to cave radio and 1750 M. The provisions of 15.111 for operation between 10 and 490 kHz:

Field Strength (Microvolts per meter measured at 300 meters) not to exceed 2400 / f(kHz).

13 microvolts at 180 kHz, 27 microvolts at 90 kHz, etc. Small signals, but it seems unlikely to me that these levels will be exceeded by portable equipment operated underground.

The 160-190 kHz area might be interesting for "guide wire" work. The railroads used to have transmitters in this region that coupled to the adjacent telegraph lines providing communications between stations and trains in motion. I think this has been completely replaced by radio (UHF/VHF) now. My first experience of LF reception occurred when I was a child riding in a car equipped with an AM receiver. The car stopped at a rail crossing and very clearly over the radio came the sound of a steam locomotive! None of the adults could even attempt an explanation of this odd event and it was not until many years later, talking Longwave with a retired railroad man on 160 M that the mystery was solved.

I don't know whether LF would have any advantage over 27 MHz with a guide wire underground but it seems like the system could be quite sensitive, particularly if the wire were tuned. FM might be used to reduce noise problems. FM systems exist that utilize wire loops around the coverage area, either for intercom or one-way use as in museums and exhibits.

Really long-haul guidewires could have little booster amps - possibly bridging some physical gaps by radio.

A letter from Jim Borglum (which I cannot find now) indicated that some would-be Lowfers working below 10 kHz in Great Britain ran into some fairly serious trouble with the law. Apparently licenses are required (in GB) and in general will not be issued for work in the AF region. I believe the problem may be that in Europe the power line carriers which we find so extensively in the 160-190 kHz region are down in the 2.5 to 15 kHz area (LF BC band occupying the higher frequencies). Considering there must be thousands of PLCs packed into a very narrow region, there may be real interference potential, particularly if experimenters are working with earth current modes and using power mains grounds as part of the loop.

**Michael Hildeke**  
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San Simeon, CA 93452

LETTERS (continued)

[ed note: Mike no longer publishes 1750 Meters: Western Update as noted in Speleonic 4; the new editor is Jim Ericson, 226 Charles St., Sunnyvale, CA 94086. The only acceptable form of subscription will be business-size SASEs.]

Mike enclosed a copy of ELF/VLF Communications Through the Earth Project Report for Calendar Year 1984 from Lawrence Livermore National Laboratory, prepared for an Air Force study of deep-based ballistic missiles. This 80-page report contains theory of buried electric and magnetic dipoles, plus summaries of experiments performed in a tunnel at Yosemite National Park, and at Lake Lynn Laboratory, USBM mining research station south of Uniontown, PA, near the WV border. A copy of the document will be donated to the NSS Library.

Editor:

I'm not up on electronics but still wade through the kHz's, etc.

I'm looking for a large cave in the southwest with a treasure in it. I think the cave could be over a mile long. The cave is in a fractured

layer of calciche (chalk) that forms the bottom of an old volcanic caldron and is maybe over 400 feet deep, but should be dry.

The "Michie Phone System" [SPELEONICS 4] seems to be about the best I've seen so far. What problems do you foresee in a mile run using this system? What would a mile of 7 / .0076" wire weigh? Is there someone I could contact to build this system for me?

**R. G. (Jerry) Babcock**  
601 Briarwood  
Marshall, Missouri 65340

The Michie Phone, which uses a single wire and ground, with high-impedance amplifiers (about 60k ohms), should work well over a 1-mile range. I do not speak from experience; there could be problems in an extremely dry environment. Seven strands of .0076" diameter copper wire weighs about 3 kilograms, plus the weight of insulation, perhaps 30%, for a total of 3.8 kg, or 8.5 pounds. Anyone interested in Jerry's project? --F.R.

----- ANNOUNCEMENTS -----

**WIRE SIZE PROBLEMS**

Numbered wire sizes cause considerable international confusion. Several different systems are used among non-metric nations. The only system commonly used in the U.S. is "AWG" (American Wire Gauge), which is the same as B&S (Browne & Sharpe). Particularly confusing is the "circular mil" unit used to measure the cross-section of wire. A circular mil is the area of a circle with a diameter 0.001 inch ( $7.85 \times 10^{-7}$  in<sup>2</sup>). The Radio Amateur's Handbook and the Handbook of Chemistry and Physics contain wire tables with metric dimensions. Authors should specify actual diameters of wires.

**NSS CAVING INFORMATION SERIES #18 REVISED**

Use of the Cave Radio in Mapping, by cave radio pioneer Bill Nixon, has been updated and expanded by Frank Reid and sent to NSS Caving Information Series coordinator Chris Amundson. Publication date is unknown at this time.

The revised version includes a section on weak-signal techniques, and a programmable-calculator solution to the depth equation.

Caving Information Series #19, How to Build a Cave Radio, needs modernization. Any volunteers?

**NOTICE TO HAMS AND RESCUERS**

Gene Harrison has Larsen VHF and UHF mobile antennas available at discount prices. Contact him at Box 1584, Leesburg, VA 22075.

Communications equipment interchangeability is important in emergency service; Eastern cave-rescue groups have standardized on Larsen-type mobile antennas, whose screw-on mounts are the same as ordinary SO-239 "UHF" coaxial connectors. (See also Gene's article about standardized 12-volt dc power connectors in SPELEONICS 2.)

**SPECIAL ISSUE ON LIGHTING**

The next SPELEONICS will be devoted to electric lights for caving. Send your article to Joe Giddens or Frank Reid. Hoping to include a bibliography, we're also looking for lists and copies of published articles about cave lights, batteries, chargers, bulbs, modifications for existing systems, etc.

## CIRCUIT DESCRIPTION, ALBERTA SPELEOLOGICAL SOCIETY CAVE RADIO

by Ian Drummond and Julian Coward, January, 1985

**4.1 Power Supply.** The power supply uses a uA723 voltage regulator to reduce the 12v battery voltage to a regulated 9v for most of the low-power circuits. The LED (D102) extinguishes if the battery voltage drops below about 11v. D103 is a reverse polarity protector, and will cause the fuse to blow if the battery is connected the wrong way. The exact output voltage is controlled by the ratio of R102/R103 and either can be trimmed if necessary. Current limiting of the 9v supply is controlled by R101 at about 65 ma and will protect the circuit in case of a short-circuit.

**4.2 Oscillator and Divider Circuits.** The carrier frequency, 114.3 kHz, is obtained by dividing the output of a crystal oscillator. Further division is used to obtain an audio tone of 1143 Hz. In this circuit a separate pulser is used to switch the audio tone on and off, but for future circuits, further division to obtain the pulse signal is recommended.

The oscillator uses a 4.0 MHz crystal in a standard circuit using a CMOS NOR gate connected as an inverter. The exact frequency can be adjusted about 100 Hz using C203. The frequency of all units should be adjusted to the same value by beating the 4 MHz signal from the units while listening on a wideband or communications receiver.

The 4569 (Q202) is a programmable two-stage frequency divider, and is connected here to give a 35-to-1 division. The output from pin 1 consists of short positive-going pulses, and the pulse shaper D201, C208 and R204 squares-up the waveform, increasing the output from the tuned circuit L201/C210. L201 is an approx. 14 mH inductor made by winding 190 turns on a Siemens B65541-L0400-A048 pot core.

The pulses from the 114.3 kHz circuit are also fed to a 100:1 frequency divider Q203. Q203 is a 4518, a two-stage divide-by-ten, with each stage having reset and inhibit lines. All pins not shown connected in Fig. 4.4 must be left open, as they are outputs.

L202 is a surplus 720 mH inductor. C205 and C206 in series tune L202 to resonance at 1143 Hz and either capacitor can be padded as necessary. Tuning is not too critical in this circuit.

The pulser uses two gates of a 4001 (Q201) connected to oscillate at about 1 Hz. D202, R207 and R208 are connected to control the duty cycle of the pulser, with the output at pin 11 going low for about 30% of the cycle. The pulse can be suppressed if pin 13 is held high, which occurs if S202 is open. Continuous tone would then be transmitted, or if S4 is operated, morse code can be sent.

**4.3 Audio Amplifier and Modulator.** The tone and speech signals are amplified and fed to the balanced modulator, which produces a double-sideband signal with the carrier suppressed.

A carbon microphone is used, powered through the trimmer R301 which controls the level of speech clipping (elimination of transient highs which

would cause overmodulation if not removed). The two diodes D301 and D302, and R303, R302 and R304 limit the audio output of the mike to about 1200 mv peak-to-peak.

The op-amp Q301 is a uA741 connected as a summing amplifier to amplify either tone or speech signals before filtering out the lower sideband and feeding the output power amplifier. R308 controls the gain and consequently the drive level applied to the output stage. C308 is used to limit the high-frequency response of Q301.

To set up the audio system, a 1140 Hz signal should be injected at C301 and the level increased until the signal between C302 and R305 just shows clipping on an oscilloscope. The RMS voltage is then measured at this point (S volts). The tone input voltage is also measured at R309 (T volts). R305 value is then calculated as  $10 \times S/T$  k-ohms. This insures speech and tone will be equally amplified by Q301. R301 is adjusted so that moderate clipping occurs (as observed by scope on the input side of R305) when speaking normally into the mike.

The balanced modulator is a 1496 chip used in a standard circuit. Good decoupling is required at pin 8 and components should be placed to minimize feedthrough from the carrier input (C308) to the output on C310, R312 or R311. The balance control (R320) is adjusted for minimum output when the tone is off and the mike disconnected. Details of setting-up single sideband systems can be found in many books, such as The Radio Amateur's Handbook.

**4.4 The Sideband Filter.** The sideband filter is tuned to a frequency of 115.4 kHz to select the upper sideband. The 3db bandwidth is 1.3 kHz and output is 80-100% of the input voltage at 115.4 kHz. The inductors were all wound with 28 AWG wire on Siemens pot-cores, B65661-L0400-A022. The windings were tightly taped and the bobbins held in place in the cores with wax, also, no slugs were used, in the interest of mechanical stability and consequently stable inductance. The tuning capacitors were silver-mica for stability and high Q.

**4.5 Power Amplifier.** The final output amplifier is a standard linear class-AB design, giving up to 10 w continuous output. L501 is wound on Siemens B65661-L0400-A022 pot core and C503 is chosen to resonate the 35-turn primary at 115.4 kHz (loaded Q is approx. 20). L502 was wound on a Siemens B65661-K0000-R030 pot core. The number of secondary turns requires a knowledge of the impedance of the antenna at 115.4 kHz and is equal to  $\sqrt{I/I}$  Where I is the impedance in ohms. Practically, the secondary is wound with several taps around the calculated value, and the tap giving maximum power output is used.

The driver transistor Q501 requires a push-on heat sink. The final stage transistors were mounted on Wakefield 601 heat sinks.

As the gain of the audio section (R308) is increased, the antenna power will increase until it reaches a plateau. The gain should be set near the top of the linear portion of the curve.

**4.6 RF Amplifier.** The receiver preamplifier is a key component and has been modified several times by us. Key features are a low-input-impedance first stage to match the antenna impedance, and narrow-band coupling transformers between stages to reduce noise and interference. Two circuits are shown here. Fig. 4.9 shows the narrow-band transformer in the second stage collector. C516A is selected to tune L503A to 115.4 kHz (Siemens B65661-L0400-A022 pot core). A gain control was added on the front panel although it is probably not necessary. Gain at 115.4 kHz is 35 db on "low" and 60 db on "high." In the field, high gain can only be used under very quiet electrical conditions and is only useful at extreme range (greater than 200 m).

Because the first stages are the most critical for noise reduction, a second modification was made, Fig. 4.9A. A FET first stage with narrow-band transformer was added and the gain control removed. Overall gain is 80 db with acceptably low noise. This circuit has only been used in the field with the large antenna (see later) and the greater range of this unit is due in part to the RF preamp, and in part to the antenna.

**4.7 Demodulator and Audio Amp.** The demodulator uses a LM373 chip which mixes a local carrier with the single-sideband signal and extracts the audio signal. The LM373 has two stages, the first is an amplifier which can provide from 40 db gain to 20 db attenuation. The gain is controlled either manually (which we do not use here) or by the level of the audio signal from the second stage. The use of the automatic gain control is convenient for speech and does not cause problems for null location at depths of up to 100 m. The circuit is a standard one except for the addition of a filter network (R406A, R407A, C422, C422A and C423A) on the audio output to remove carrier frequencies. The audio amplifier Q405 has sufficient gain at 114 kHz to cause feedback and oscillation if the carrier leakage is not removed.

The LM373 chip is reported to be no longer available, but the ECG 800 is supposed to be a direct replacement.

The audio amp, Fig. 4.12, uses a standard integrated circuit to power the 8-ohm headphones.

**4.8 Audio Filter.** The filter enhances reception of tone in electrically noisy areas. It consists of a standard design (see Amateur Radio Handbook) using a quad op-amp connected as a four-stage twin-T circuit. Each stage has a Q of 5 and a gain of 1.5 with a centre frequency of 1143 Hz. The capacitors should be polystyrene and the resistors all 5%.

**4.9 Alarm** If a radio is left on "receive" with the alarm on, a tone signal from another radio will give an audible alarm. This feature is useful for underground camps and allows contact at other than prearranged times. The circuit is based on a uA456 tone decoder. C493, R495 and R496 determine the frequency which is detected (1143 Hz) and the capacitors on pins 1 and 2 control the number of cycles before alarm. They are set fairly large to give noise immunity but still trigger on a pulsed tone signal.

**5.1 The Antennas.** The antenna is used for both transmission and reception. The original antennas worked, were not too large to use in overgrown

surface areas, but had little else to recommend them, being expensive, time-consuming to make, and subject to very high electrical voltages. They consisted of a single-turn primary coil and a 70-turn tuned secondary. The coil is wound as a 0.71 m square loop, held fairly rigid by a wooden frame but can be folded up for transportation.

A second type of antenna was made which is cheaper, easier to make, and while larger and somewhat more awkward to handle, has far superior performance. At a given distance the magnetic field in transmission is 20x as large and in reception it absorbs 3x the power from the field. (The design of antennas is the subject of a series of articles in SPELEONICS.)

The original antenna consisted of plexiglass and ABS plastic spider and four wooden spreaders, well-varnished as waterproofing. The 70 turns of 28 AWG magnet wire were wound on the assembled frame in the form of a flat ribbon (important!). The completed ribbon was liberally coated with contact cement to keep its shape and when thoroughly dry, wrapped with butyl rubber self-sealing tape using a 50% overlap. The termination and capacitor box was then constructed by epoxy-gluing together PC board material to form a box 1x1x3 inches. The box was taped to the secondary coil and the single turn primary of 18 AWG PVC-insulated wire added and connected to the BNC connector in the box. The ends of the secondary coil are brought into the box and the coil finished with a second wrap of butyl tape followed by a final wrap of zinc oxide adhesive bandage.

To tune the antenna a 115.4 kHz signal is fed to the primary and the necessary capacitors added across the secondary windings. The capacitors must be 6-kv types with low temperature coefficients. We used S2L types of 4.7 to 15 pf connected in parallel to give a total of about 80 pf.

The Q of the antenna is about 80, so the tuning is quite critical and final tuning must be done with the capacitors installed in the box and the indicating neon lamp connected. The neon is only connected to one lead, as stray capacitance is enough to strike it when transmitting. After final tuning, the box is filled with wax.

The larger antenna has similar framework of spider and four spreaders but is 1.6 m square. The coil consists of 2 turns of two-conductor zip-cord 16 AWG wire connected to give a four-turn winding, tapped one turn from the bottom. The main tuning capacitor is a 500-v, 0.05 uf unit selected to give a high Q. A DIP switch can be used to select trimming capacitors, allowing some tuning to be done in the field if necessary. An indicator neon is connected (at both terminals) via a 220 k resistor across the secondary coil.

#### References:

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Coward, J, Drummond, I. Construction and testing of an underground radio. A report to the Alberta Gov't Workers' Health, Safety and Compensation Dept. 1983.

Drummond, Ian, Cave Radio Update. NSS News. vol 42, #12, p366-368, (1984)

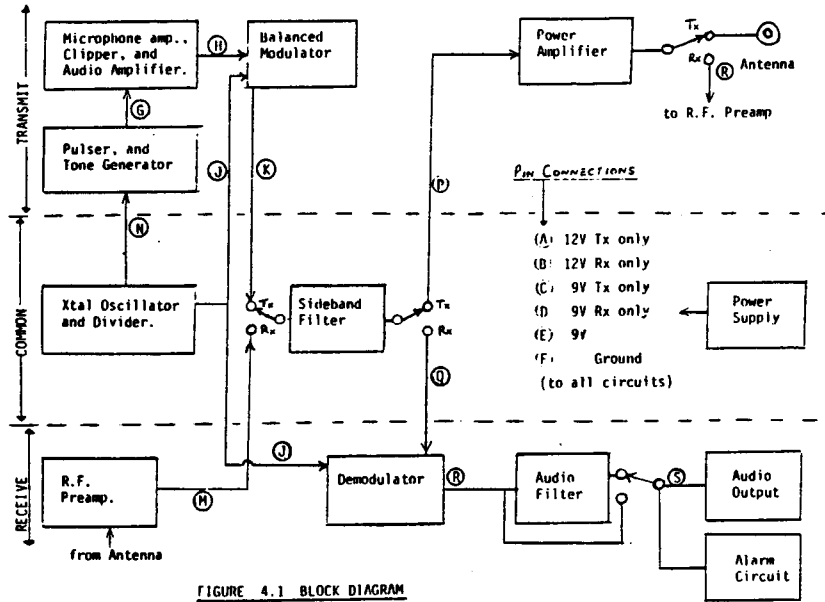


FIGURE 4.1 BLOCK DIAGRAM

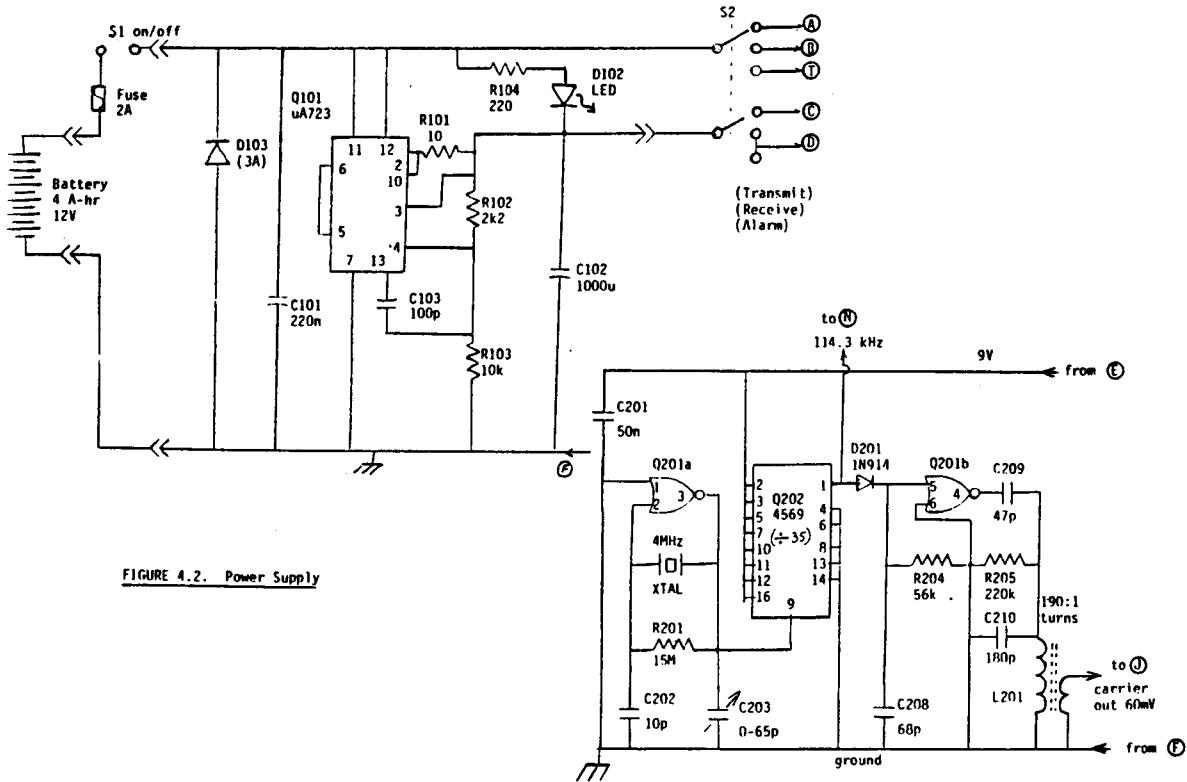


FIGURE 4.2. Power Supply

FIGURE 4.3. XTAL OSCILLATOR and DIVIDER

